

# Wind capacity cost curves for off-shore versus on-shore wind / negative prices and curtailment of wind power

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# Wind capacity cost curves for off-shore versus on-shore wind / negative prices and curtailment of wind power

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# Wind cost curves and their comparison?

**AGENDA**

Background – Cost curves and efficient deployment of renewable energy sources

**Wind cost curves for Denmark**

- Off-shore cost curve
- Off-shore cost drivers
- Onshore costs
- Comparison and gap for adding transaction and acceptance costs

**Wind cost curves in comparison to other countries**

- Norway
- Netherlands

**Price effects and diversification from mixing onshore and off-shore wind**

- Correlation of generation between wind categories?
- Negative prices - yes
- Curtailment of wind generation

# Background: Cost curves

***Objective: To identify the least cost renewables investment options to meet national or EU targets for renewables in power generation***

***Used as input for optimisation models***

**Total lifetime generation costs including investment and operational costs**

- Levelized costs: average cost per generated unit (kWh)
- Comparison between technologies including investment cost and with different generation profiles (full load hours)

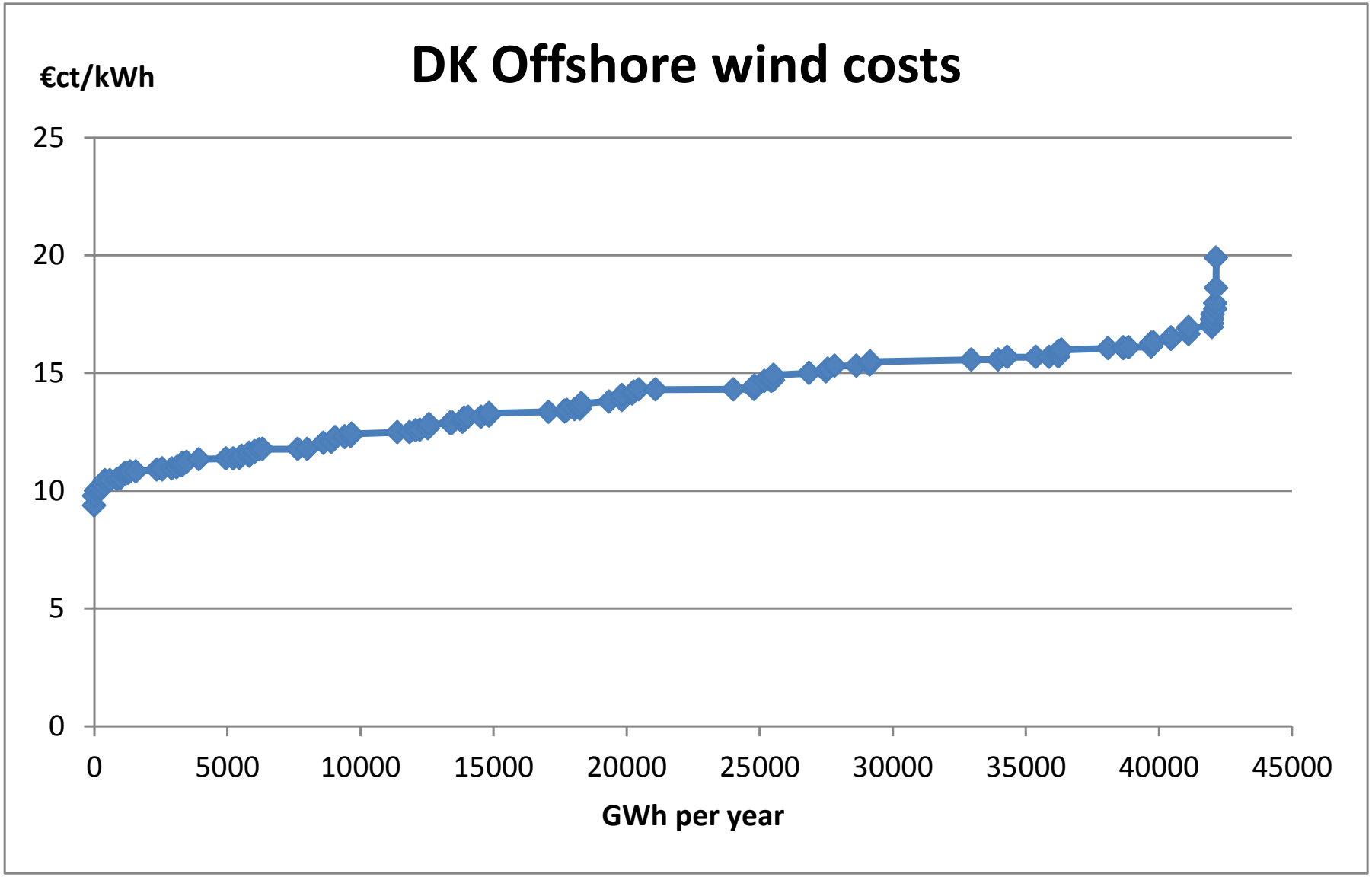
**Issues with levelized cost curves**

- Do not distinguish between time of generation (generation at different hours has very different value)
- Difficult to compare technologies with very different lifetime
- Cost curves are normally static - the real world is not

**Based on database from European projects 2010-2013: Resolve and Res4Less**

- Covering all Member States and all renewable technology country specific costs and potentials

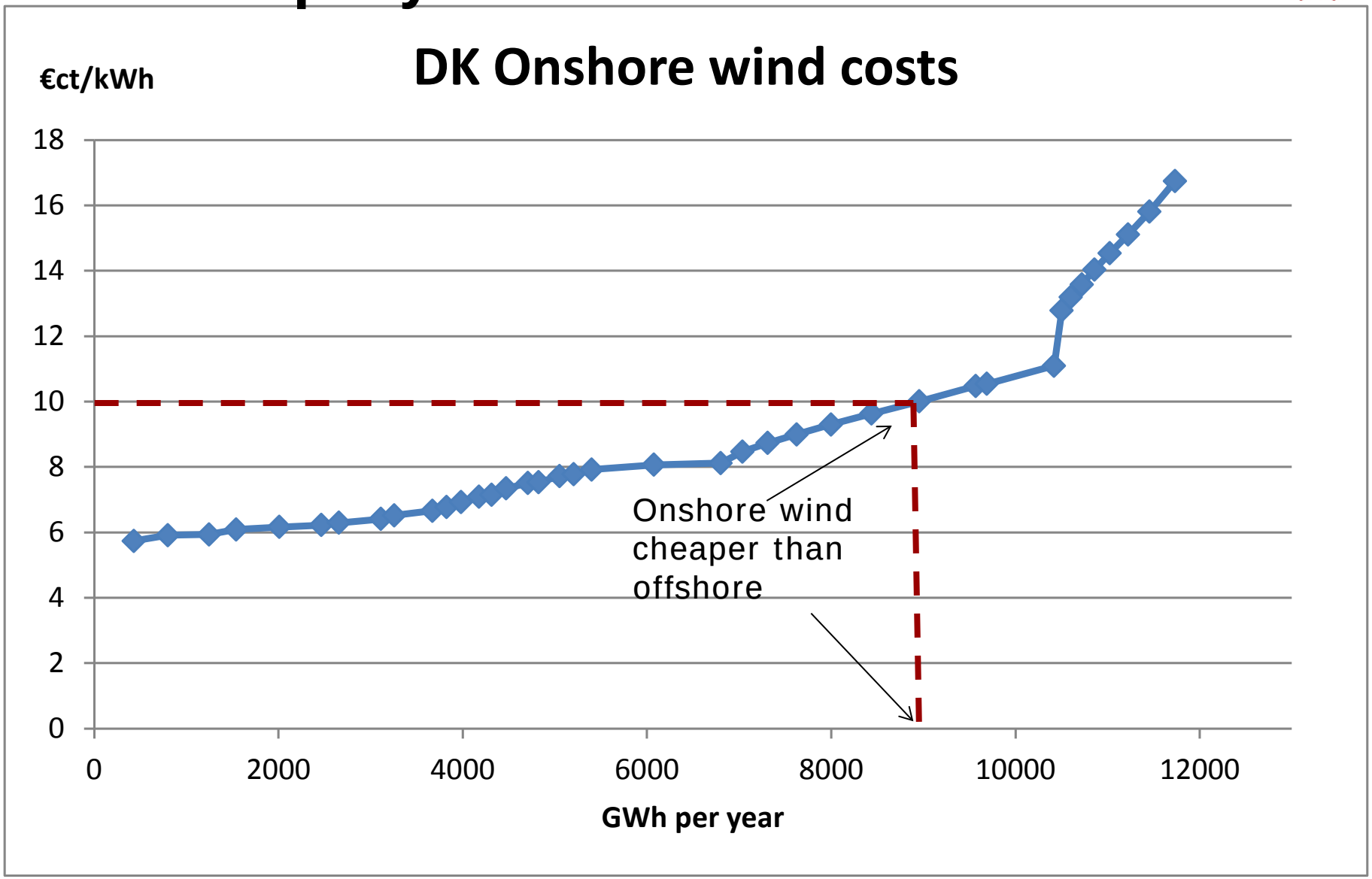
# Off shore cost in the range 10-20 €ct/kWh



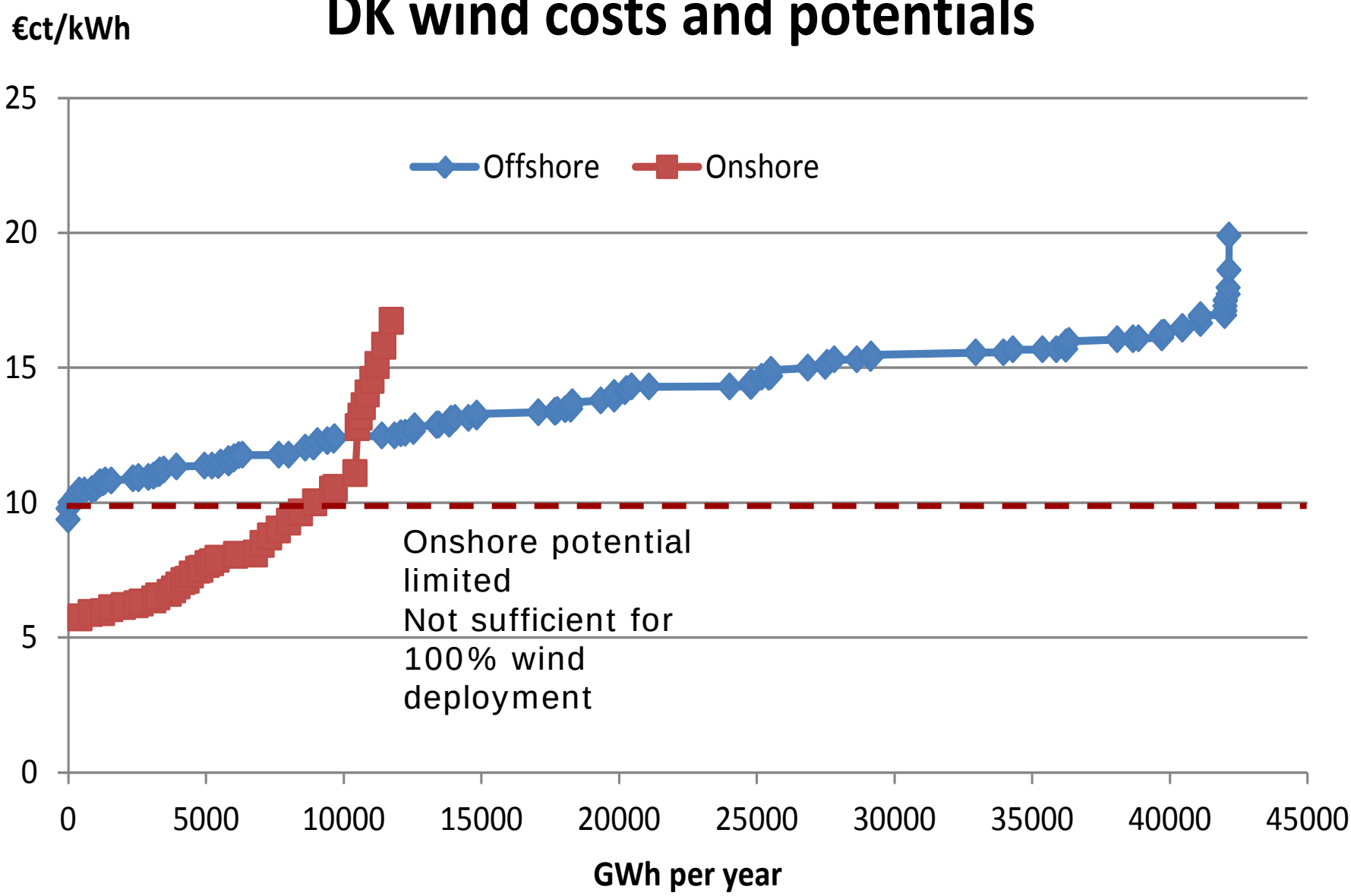
# Off shore basic cost drivers

- Distance from shore: Cost of Cables etc.
  - 0-20 km
  - 20-50 km
  - 50-100 km
  - 100-200 km
- Depth: Cost of Foundations etc. (wawes)
  - 0-20 m
  - 20-30 m
  - 30-50 m
  - >50 m
- Wind speed: (generation potential)
  - 9-10 m/s
  - 10-11 m/s
- Seabed condition
- Distance from service and support port

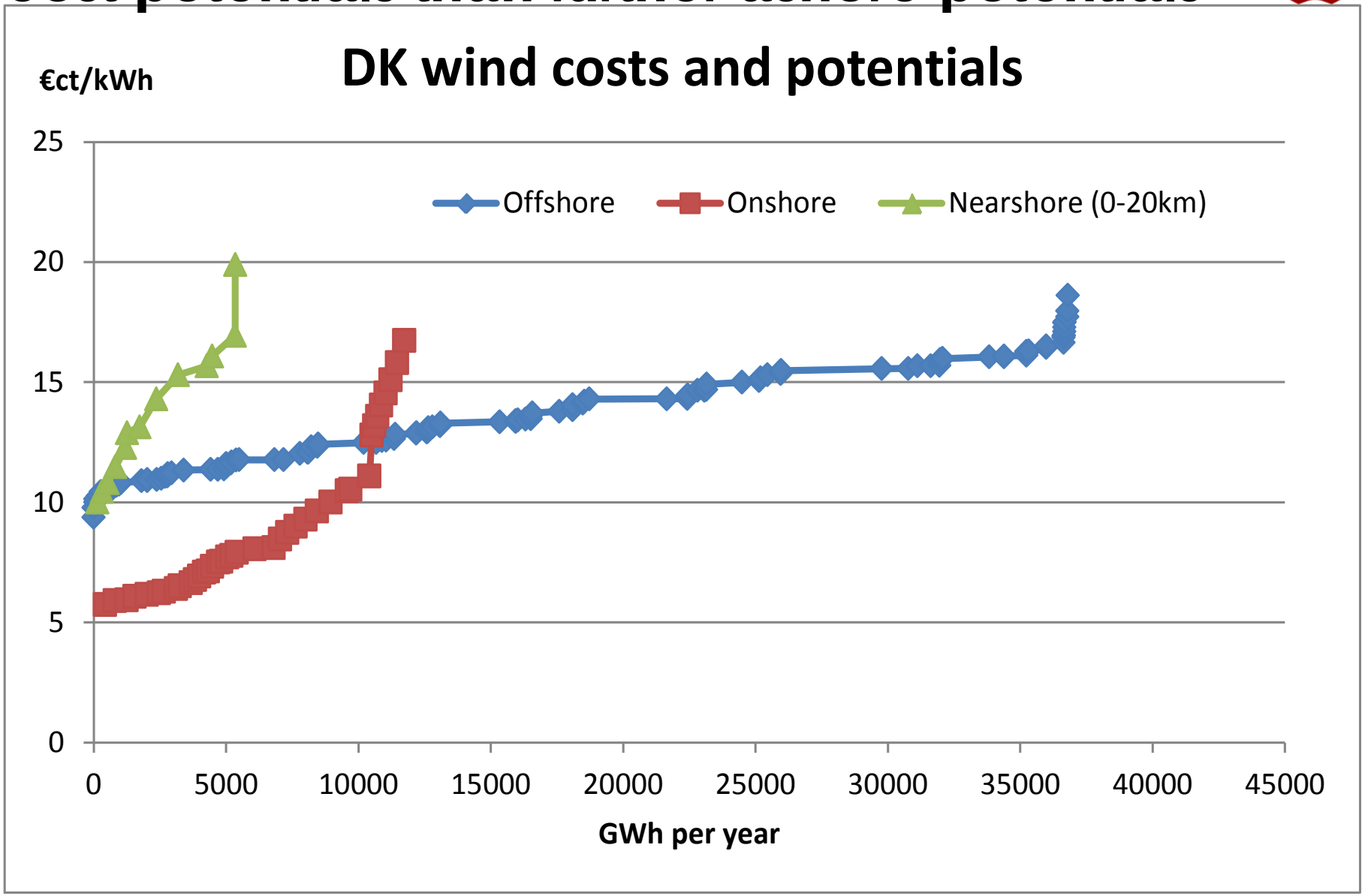
# Onshore cost in the range 6-10 €ct/kWh for 9000 GWh per year



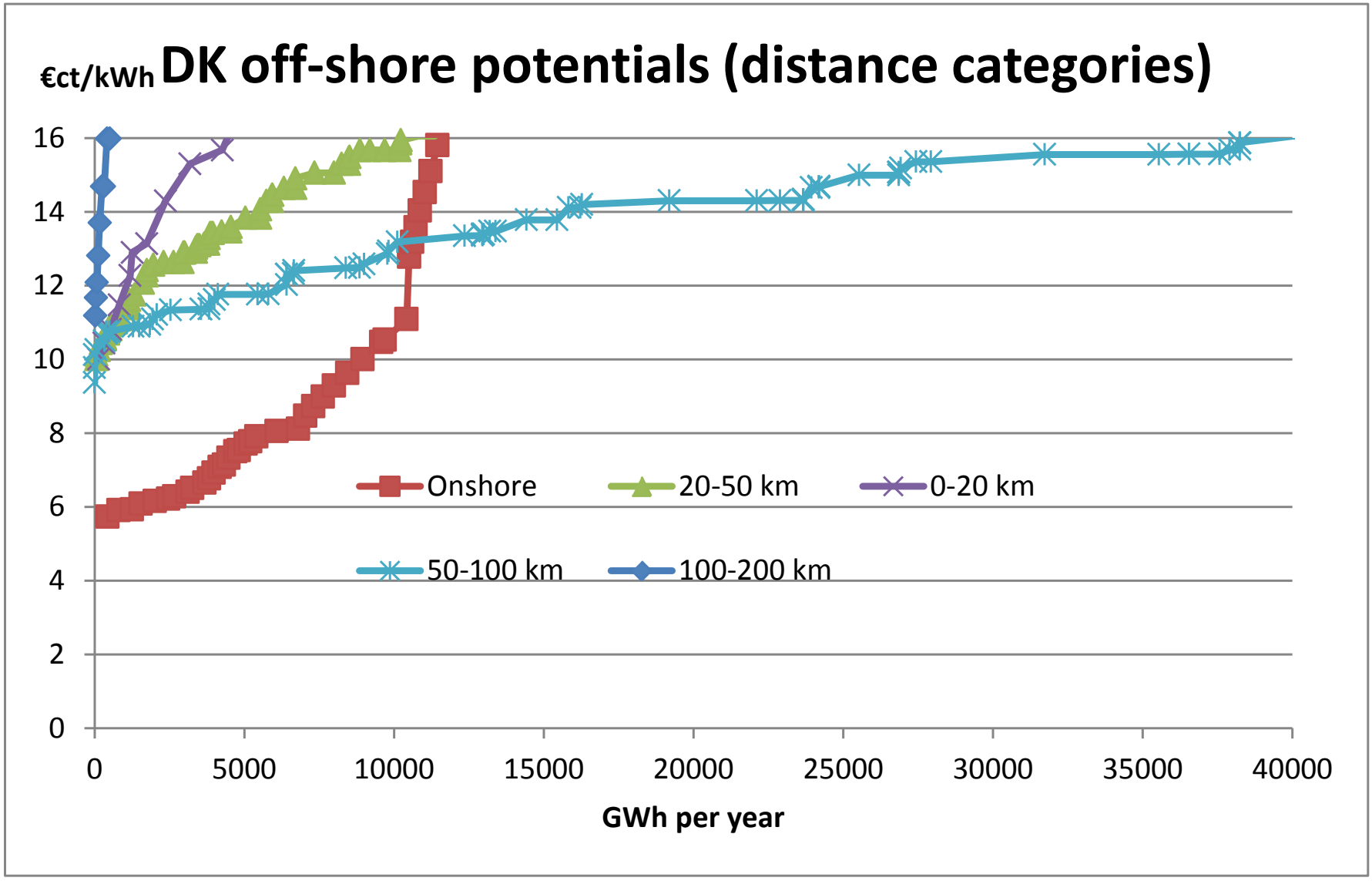
# DK wind costs and potentials



# Near-shore data do not suggest cheaper cost potentials than further ashore potentials



# Distance from shore and cost curves



# Off-shore versus onshore: Barriers and acceptance issues limits onshore development

- The cost advantage of onshore is clear but onshore development in DK has been rather slow during the last 5-10 years

- Preferences against onshore wind limits the sites actually available for onshore wind development

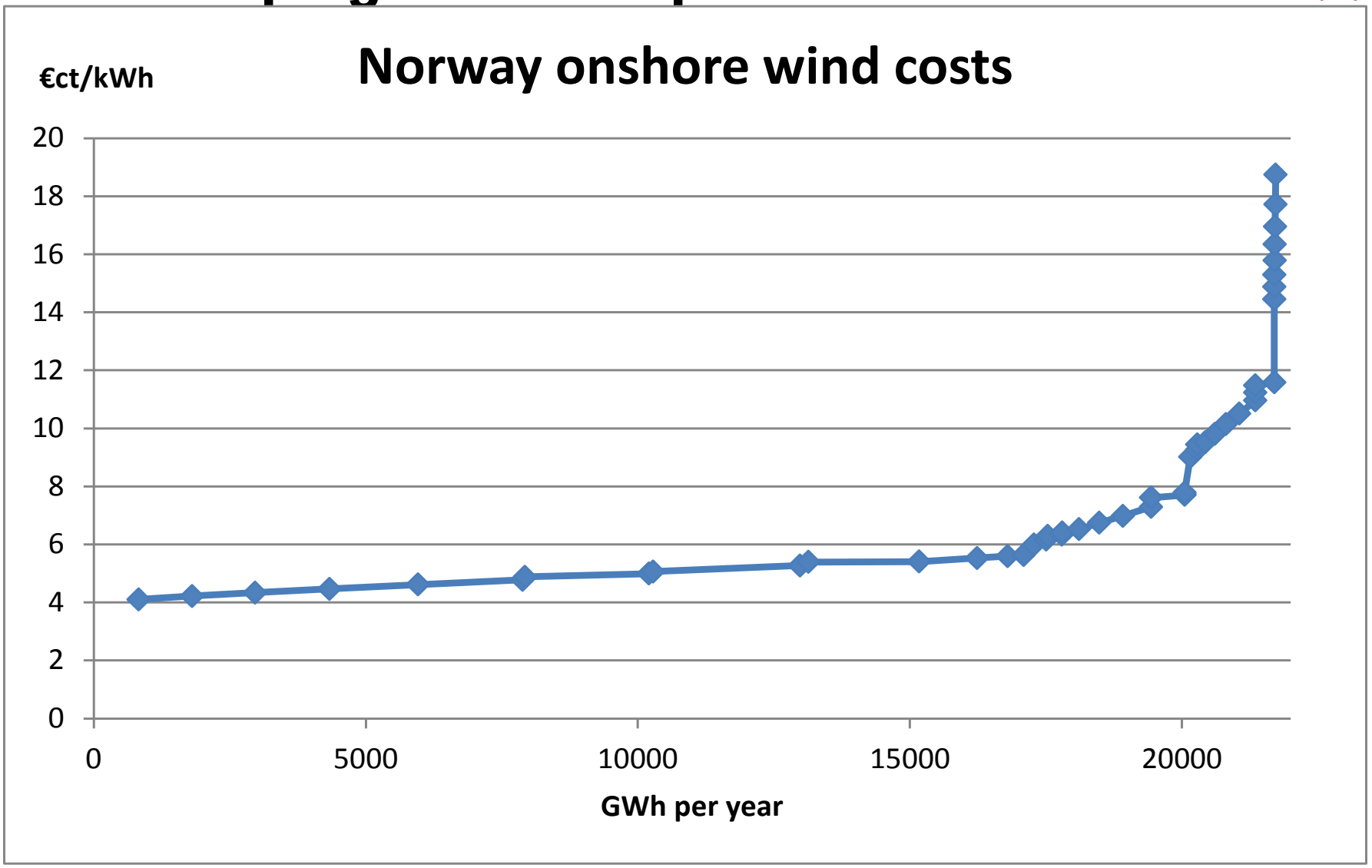
- Additional costs have to be added to facilitate further onshore development
  - Compensation payments (individual neighbours) can be brought to court
  - Green fund - Support for municipalities
  - Local minimum ownership (20%)
  - Developer risk of delay and spending on procedures/hearings increases basic technology costs

- Is the cost gap sufficiently large to account for these additional acceptance cost?
  - Probably yes for some part of the onshore potential
  - We investigate this in the Wind2050 Danish research project

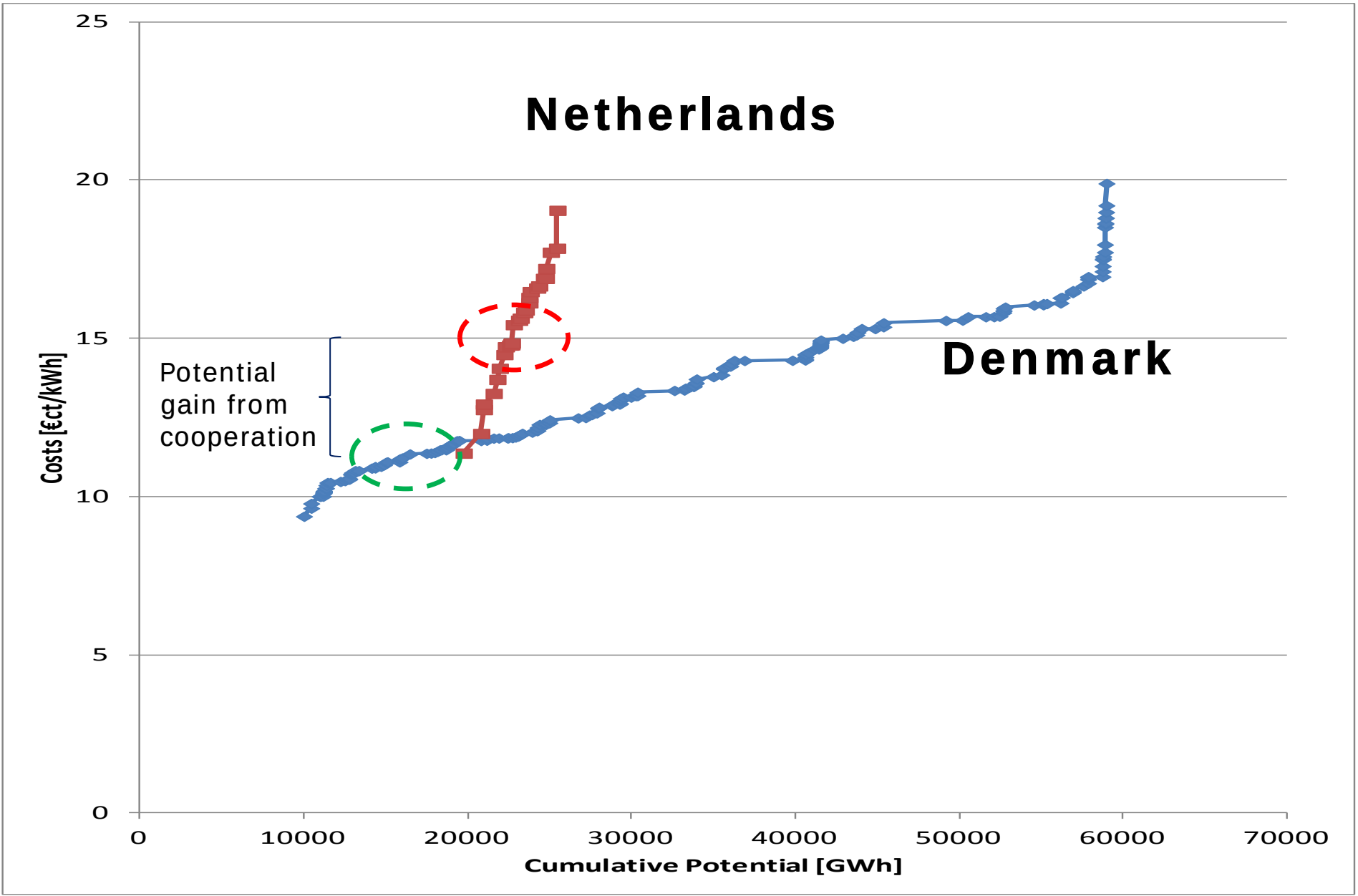
# Distance from shore and public preferences

- Distance from shore: Cost of Cables etc and depht (foundation costs) traded for public acceptance
  - 0-20 km
  - 20-50 km
  - 50-100 km
  - 100-200 km
- Preferences for placing further ashore - miss-match off distance categories in present dataset for Wind2050 project
  - 10 km
  - 15 km
  - >20 km
  - above that no significant difference/effect

# Wind cost curve for Norway and the benefit of developing here compared to DK



# Offshore wind costs 2020



**Denmark have a politically agreed target for reaching a fossil fuel free energy consumption in the year 2050**

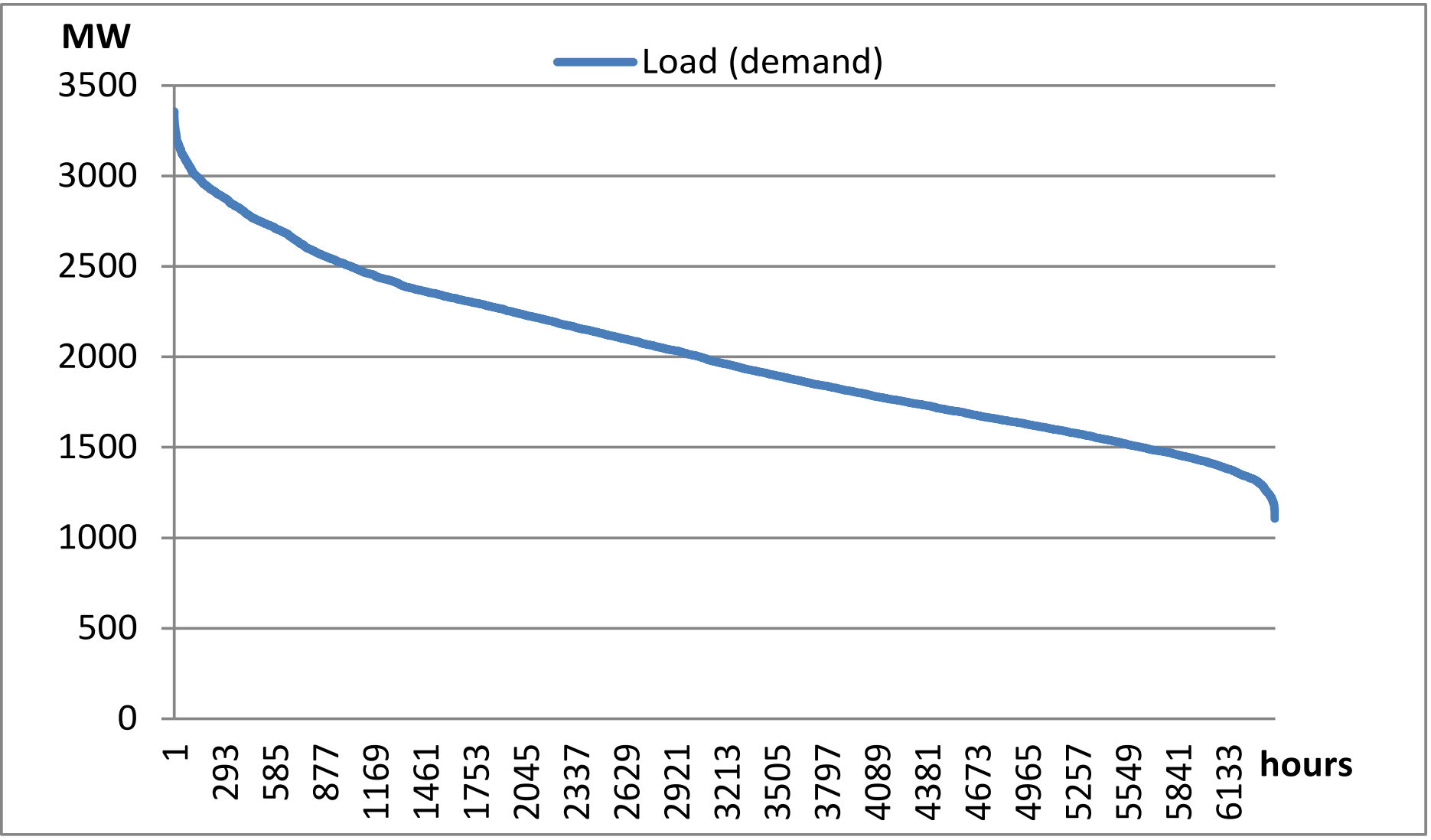
**Wind energy is relatively cheap and will be a main contributor to this development**
**Target for 2020 is 50% of total electricity**
**For 2014 achieved around 40%**

# Power market price effects of renewables?

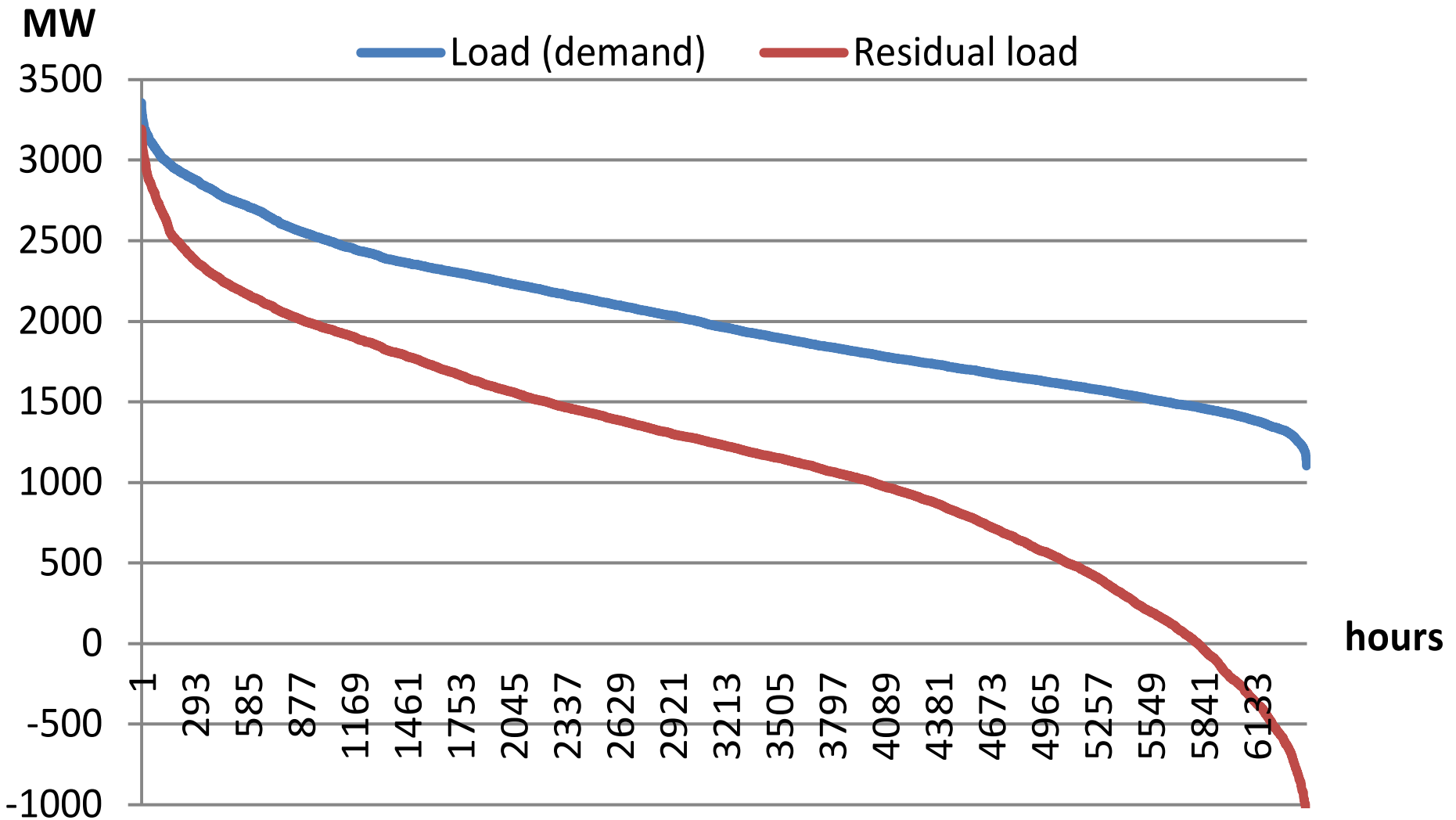
# Adding renewable capacity and the short term price effect

- Average wholesale power price is reduced
- Price is reduced the most when demand is high (peak load) and the least when demand is low
- The effect is the same as when adding other low variable cost generation. Base load technologies with low marginal cost would also shift the supply curve to the right.
- The relative effect for consumer price is not as great, since the network costs and all the taxes are added to the wholesale price

# Load duration curve Denmark West January-September 2013



# Subtracting the wind generation
# Denmark West January-September 2013



# Electricity price and renewable generator revenues

- Renewable generators receive support
  - feed-in tariffs
  - premiums
  - green certificates
  - investment grants or tax credits

**So why does prices matter for renewables?**

- First
  - premiums create some market dependence
  - green certificates imply high market price dependence
  - feed-in given as fixed term (15 years) support and afterwards 100% market!
- Secondly
  - Most utilities portfolios include intermittent generation and conventional generation
  - Theirs and competitors investment in intermittent generation will influence the price patterns of power markets and their total revenues

# Wind generator revenue and the value of the power generated from wind

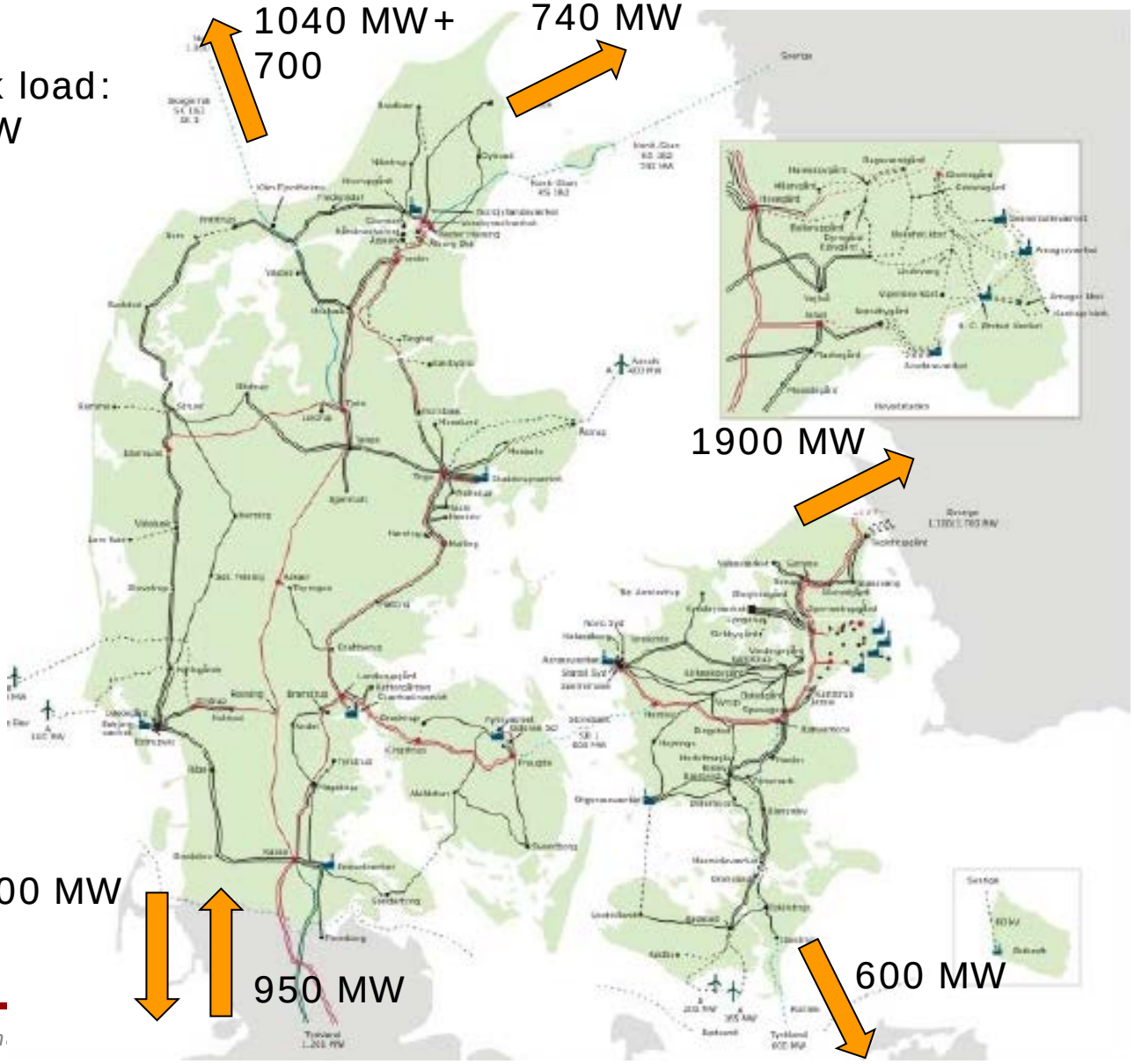
**Table 1 Wind generators market based revenues in the Western Denmark price area**

| | Area Price €/MWh (direct average of hours) | Wind average price €/MWh | Difference €/MWh | Wind price relative to market | Wind generation (GWh) | Potential loss mill. € |
|---|---|---|---|---|---|---|
| 2006 | 44.19 | 40.54 | 3.64 | 92% | 4614 | 16.8 |
| 2007 | 32.40 | 28.66 | 3.74 | 88% | 5562 | 20.8 |
| 2008 | 56.42 | 51.20 | 5.22 | 91% | 5190 | 27.1 |

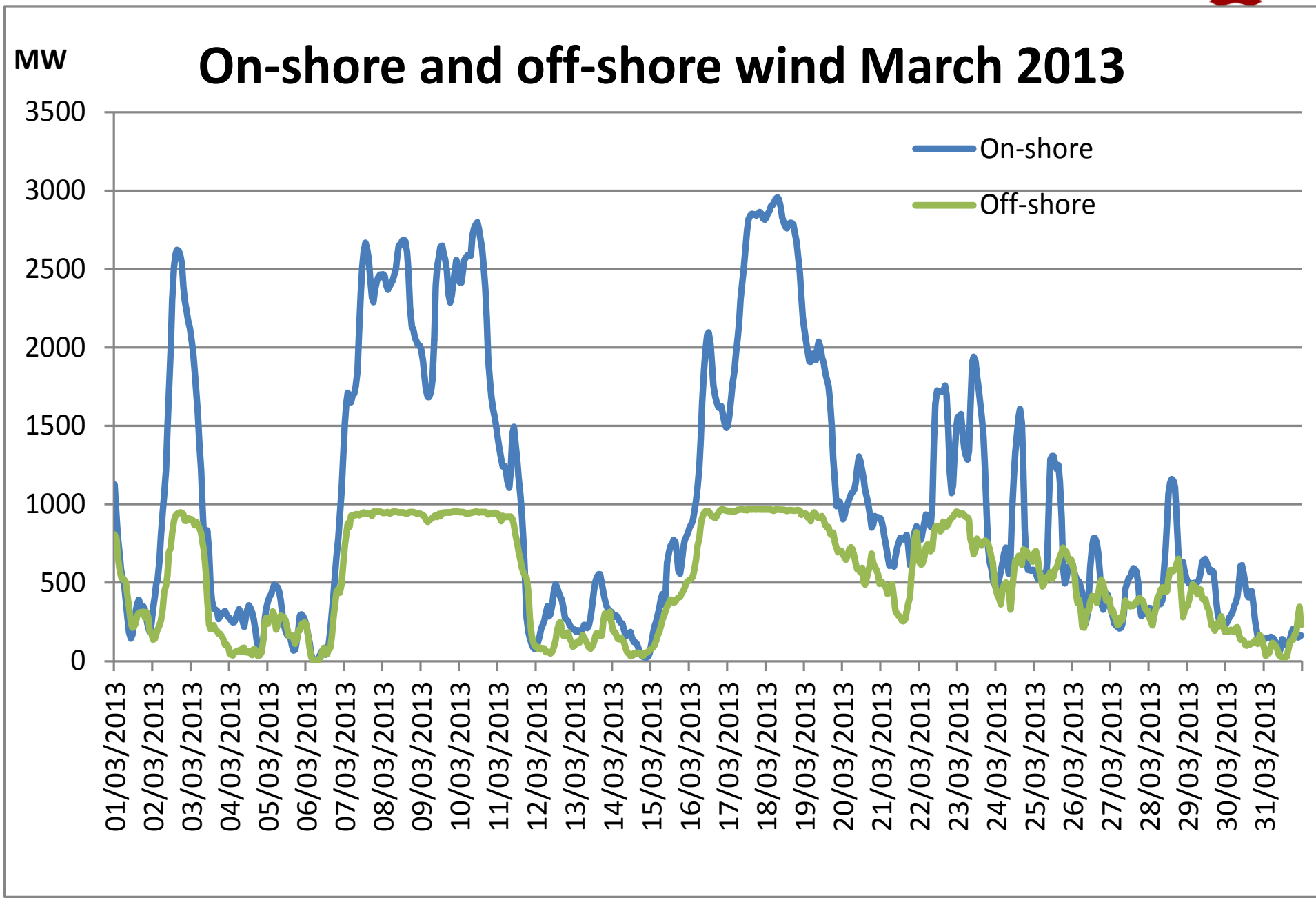
**On average the wind generation has a 10% lower value than the average market willingness to pay**

# Strong interconnections and additions facilitate use of pumped storage in reservoirs

DK peak load:
6500 MW



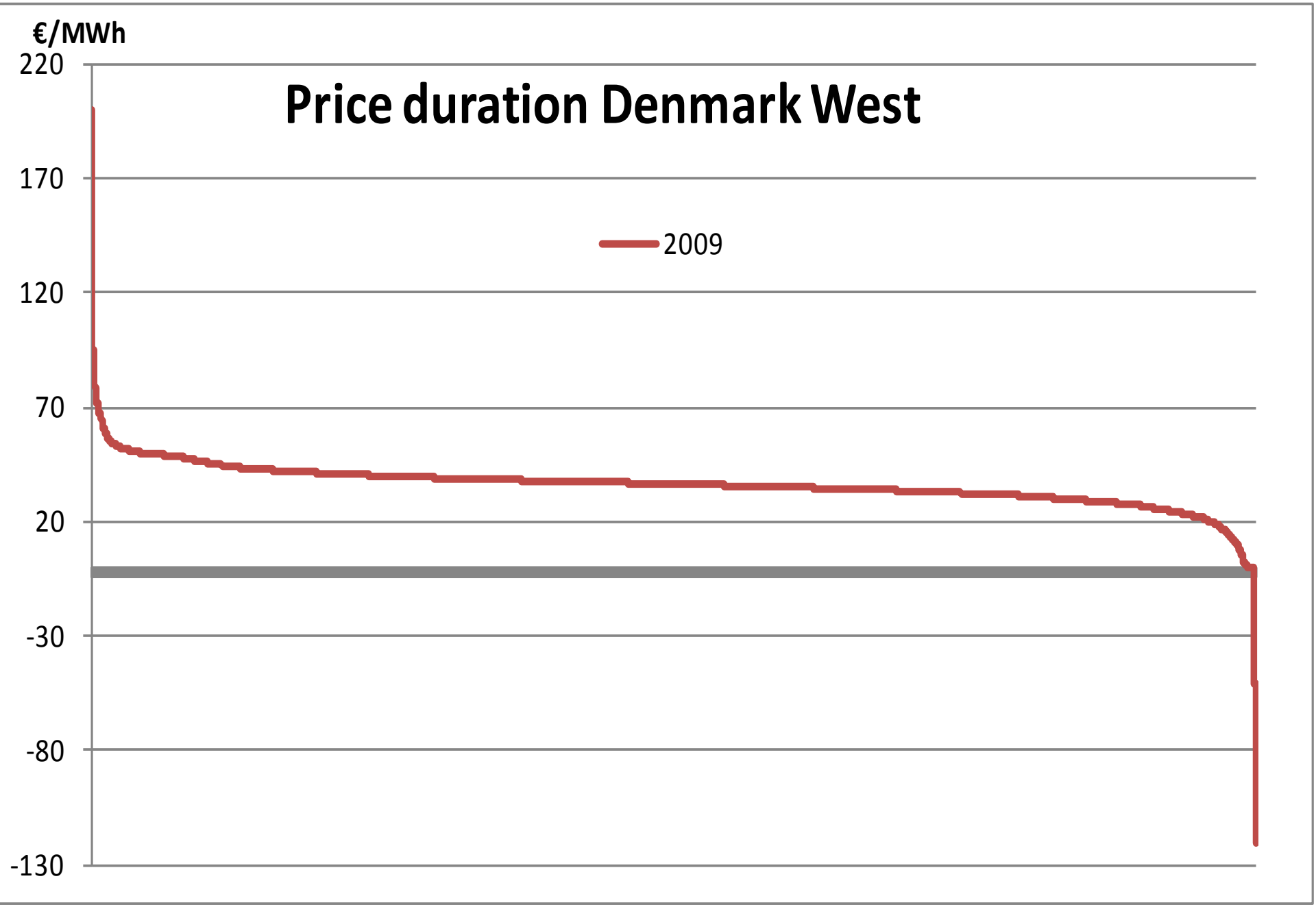
# Diversify renewable sources and location has benefits

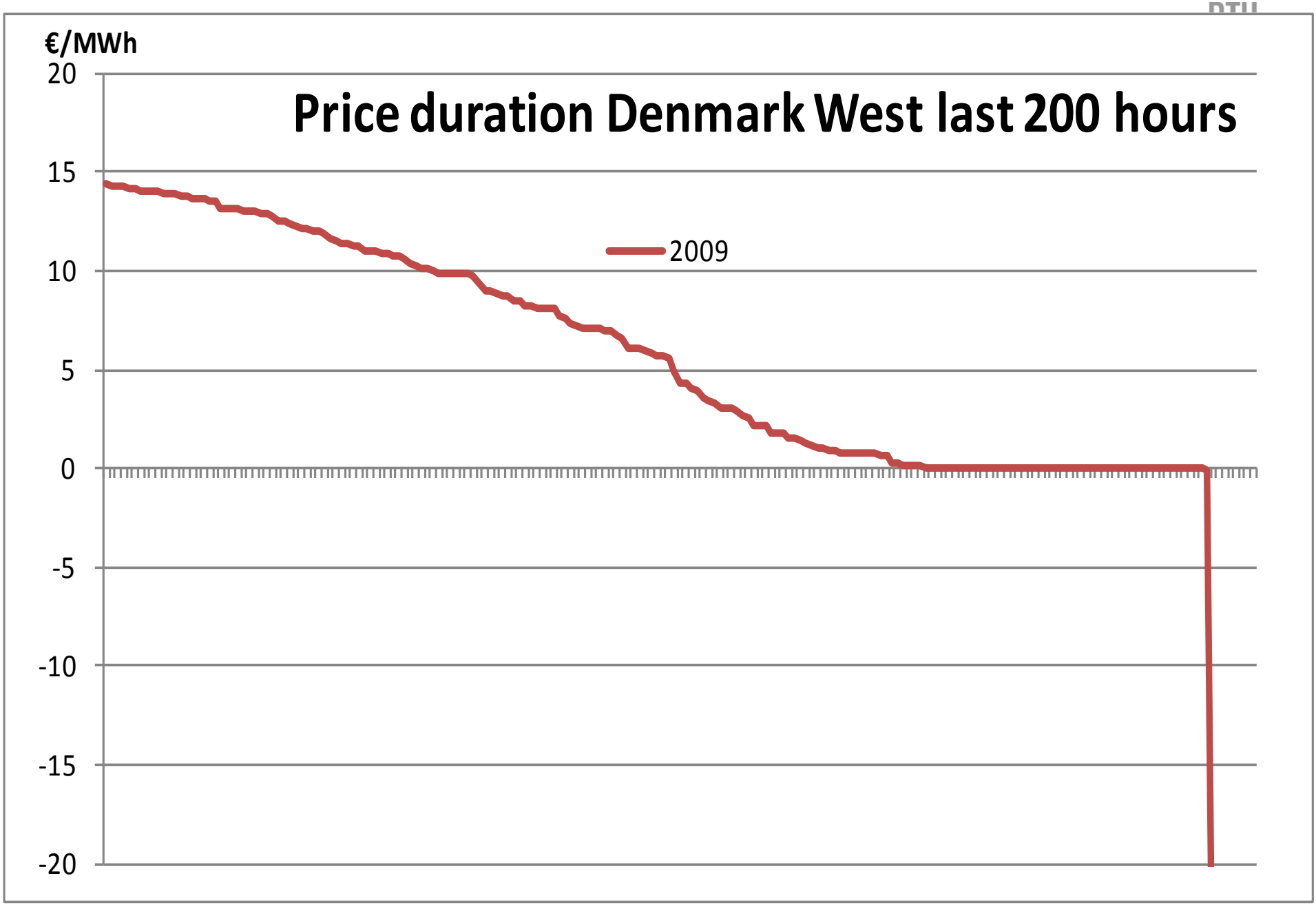


# Negative prices and curtailment of wind?

# Negative prices for electricity

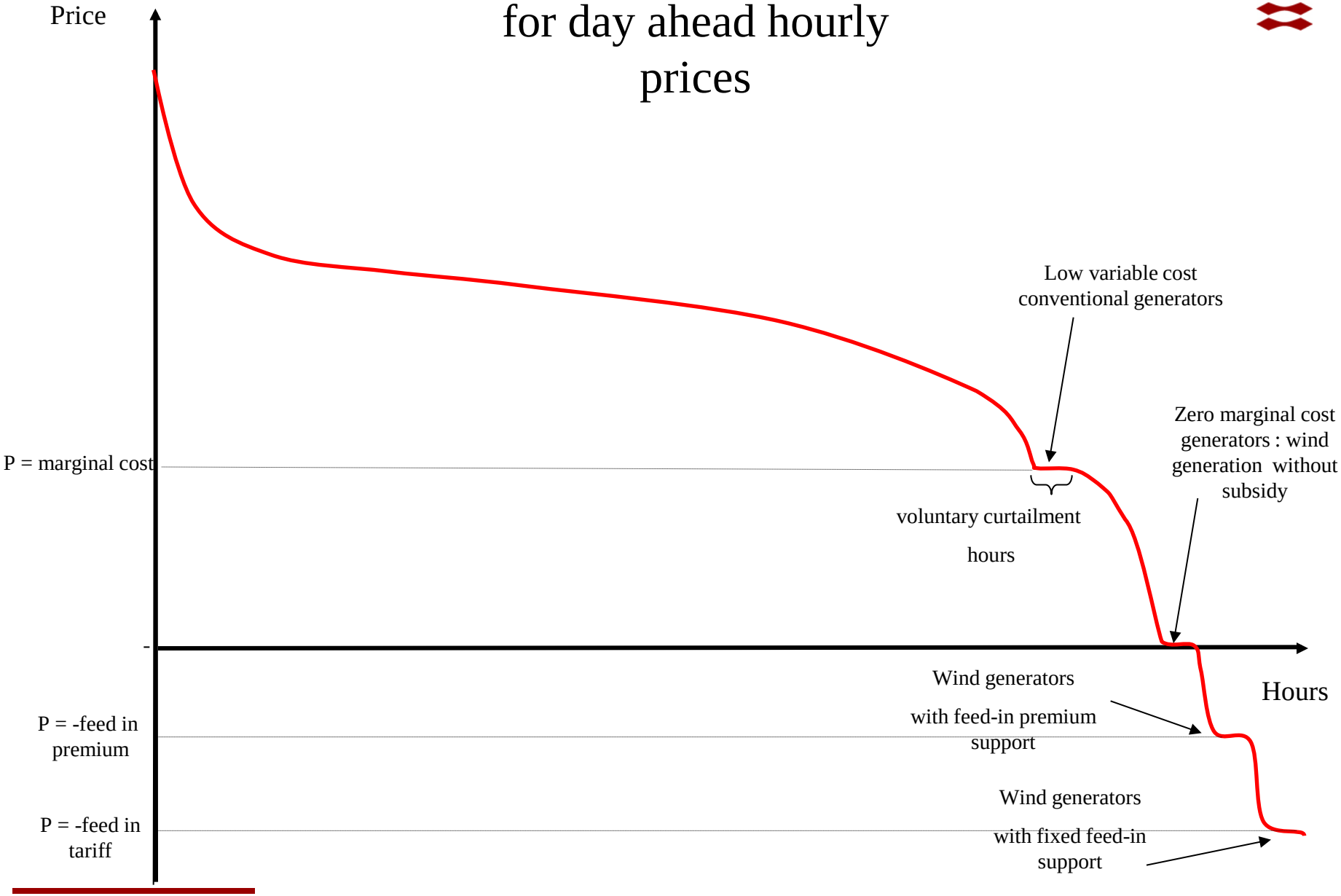
- Does not sound logical
- The marginal value of using more electricity is negative?
- Does not fit with normal assumptions
- There are good explanations for negative prices in power markets
- Important to allow the negative price signals passed to all generators for efficient allocation of production


€/MWh
220
170
120
70
20
-30
-80
-130
Price duration Denmark West
2009

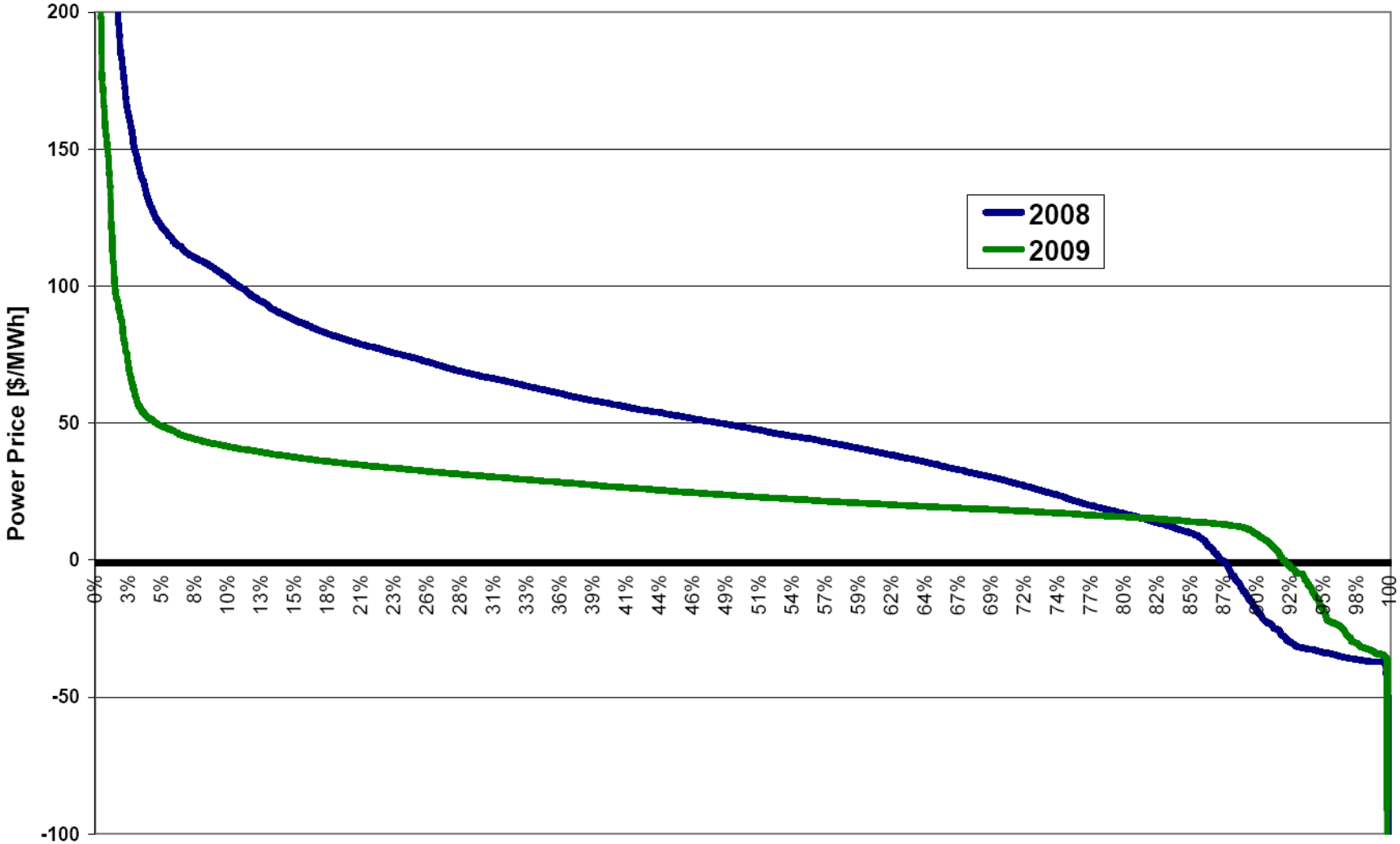

€/MWh
20
15
10
5
0
-5
-10
-15
-20
Price duration Denmark West last 200 hours
2009

# Curtailment of generation as an option?

# Price duration curve for day ahead hourly prices



# Price duration curves – Texas west




Source: ERCOT (2010)

# Negative prices: Explanation and solution

- Stop and start costs for conventional generators (minimum up and down times)
- Renewable generators are subsidised (feed-in tariff or production based tax credits)
- Renewable generation stay online as long as the negative price is less than the support
- Solution:
  - use dynamic tariffs (tax) element of consumer price reduced when zero wholesale price
  - instruct renewables to shut down – involuntarily curtailment
  - reduce/remove the support when power prices are zero or below – voluntary curtailment
- Result: Much less zero and negative prices after a bit of learning

# *Thank you for your attention!*

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